

**A METHOD OF DISTRIBUTING ROTOR BLADES IN A TURBOMACHINE****Field of the invention**

5       The present invention relates to the general field of rotors for fans, compressors, or turbines in turbomachines, and more particularly it relates to a method of distributing the blades of turbomachine rotors.

**Prior art**

10      The way in which the blades are distributed on the rotor of a turbomachine is of great importance for the behavior (balance) of such blades that move in operation. Poor distribution leads to unbalance due to the moving blades behaving differently under the same centrifugal 15 loading. Such unbalance gives rise to high levels of vibration having a non-negligible impact on the mechanical and acoustic characteristics of the turbomachine and can, in the extreme, lead to destruction of the moving blades, of the turbomachine, and of its 20 environment (in the field of aviation, that can be the aircraft in which the turbomachine is fitted, for example).

**Object and summary of the invention**

25      An object of the present invention is thus to provide a method of improving the distribution of the blades of a turbomachine rotor so as to obtain better balance in operation. Another object of the invention is to propose a method of distribution which remains 30 applicable during subsequent maintenance operations that leads to individual blades being changed.

These objects are achieved by a method of distributing the blades of a turbomachine rotor in which the radial and tangential static moments of a plurality 35 of blades for making a rotor are initially measured, and then the blades are classified in pairs on the basis of a determined selection criterion depending on said

previously measured two static moments, and finally the blades of the selected pairs are mounted one by one on the rotor in diametrically opposite positions.

Thus, by this specific method, the blades are  
5 automatically balanced regardless of their operating conditions. The residual unbalance generated by deformation of the blades is well controlled.

The selection criterion consists in determining for  
two given blades both a radial static moment difference  
10 and a tangential static moment difference, and in verifying that these two differences are respectively not greater than a first determined value and not greater than a second determined value. Preferably, the first and second determined values are respectively  $2 \times 10^{-4}$  meter  
15 kilograms (m.kg) and  $4 \times 10^{-4}$  m.kg.

Advantageously, the axial static moment of said plurality of blades is also measured, and the blades are classified in pairs while taking account of the axial static moment as measured in this way, the selection  
20 criterion consisting in determining an axial static moment difference between said two blades and in verifying that it is not greater than a third determined value, preferably  $4 \times 10^{-4}$  m.kg.

The combined static moment of said plurality of  
25 blades is also calculated and the classification in pairs may be performed while taking account of the combined static moment as calculated in this way, the selection criterion consisting in determining the unbalance of the residual radial, tangential, and axial static moments of  
30 the plurality of blades and in verifying that it is not greater than a fourth determined value, preferably  $1 \times 10^{-4}$  m.kg.

#### **Brief description of the drawings**

35 The characteristics and advantages of the present invention appear more clearly from the following

description made by way of non-limiting indication and with reference to the accompanying drawings, in which:

- Figure 1 shows a turbomachine rotor fitted with blades;
- 5 · Figure 2 is a detail view of one particular blade of the Figure 1 rotor;
- Figure 3 is a diagrammatic view of a machine for measuring the radial static moment of the Figure 2 blade; and
- 10 · Figures 4A to 7B are examples of diagrams showing the distribution of the static moments of the rotor blades of Figure 1.

#### **Detailed description of a preferred embodiment**

15 Figure 1 shows a turbomachine rotor conventionally comprising a central disk 8 having a plurality of blades 10 mounted on its circumference. The number of blades is even, for example 24 blades for a fan rotor.

20 Figure 2 is a detail view of one particular blade of the rotor. This blade 10 is in the form of a twisted wing with a blade root 12, e.g. in the shape of a fir tree, so as to provide a fixed connection with the drum of the rotor. This figure also shows the axis 14 of the rotor (which is also the axis of the turbomachine), the center of gravity G of the blade, and the longitudinal axis 16 of the blade (perpendicular to the axis of the rotor and passing through G). These axes enable static moments of the blade to be defined in three dimensions.

25 Firstly there are the radial static moment (R), secondly the tangential static moment (T), and thirdly the axial static moment (A), with the second and third components of the static moment being defined relative to the longitudinal axis 16. These three components can be measured on each blade of a rotor using suitable known machines, for example the precision balance shown in

30 Figure 3.

35

The balance 20 has previously calibrated 3D static moments and serves to measure the radial and axial static moments. To do this, the blade 10 is positioned in centrifuged operation on an engagement disk 22 which is 5 rotated. A counterweight 24 associated with an adjustment ring 26 enables rotation to be balanced. The static moment is equal to the product of the lever arm D (defined relative to the reference R of the balance) multiplied by the mass M applied at the center of gravity 10 G of the blade. This machine, which can also measure the tangential static moment by turning the engagement disk 22 through 90°, is well known and it is not appropriate to describe it in detail herein.

In a preferred embodiment of the invention, in order 15 to distribute the blades of a turbomachine rotor in such a manner as to guarantee good balance in operation, a first step is to measure the radial and tangential static moments of a plurality of blades for use in making a rotor, and then the blades are classified in pairs using 20 a determined selection criterion which depends on the measurements obtained for these two static moments, and finally the blades of selected pairs (i.e. pairs that are suitable and have therefore not been rejected) are mounted one by one on the rotor drum in diametrically 25 opposite positions (0°-180°). In another implementation, it is also possible to measure the axial static moment of each of the blades, and the selection criterion then includes this additional measurement.

The selection criterion enabling the blades to be 30 classified as acceptable blades and blades to be rejected relies on calculating static moment differences between two blades that are to form a pair. The idea is firstly to determine a radial static moment difference between two given blades, and secondly to determine a tangential static moment difference between the same two blades, and 35 then to verify that these two differences are respectively not greater than a first determined value

and not greater than a second determined value. Under such circumstances, the blades are considered as being suitable for mounting on the rotor that is being built, whereas otherwise they are rejected.

5 These two maximum difference values that determine whether or not blades are rejected are preferably equal respectively to  $2 \times 10^{-4}$  m.kg (i.e. 200 centimeter grams (cm.g)) and  $4 \times 10^{-4}$  m.kg (400 cm.g).

This selection criterion may naturally be extended  
10 to include the axial component of the static moment,  
which is then also determined for the pair of blades  
under analysis, the maximum difference in axial static  
moment beyond which the blade must be rejected then being  
compared with a third value that is likewise equal to  
15  $4 \times 10^{-4}$  m.kg (400 cm.g). Naturally, the invention is not  
limited to these particular predetermined limit values,  
and smaller values could indeed be envisaged, for example  
respectively 200 cm.g, 300 cm.g, and 200 cm.g, providing  
a higher reject rate can be accepted (or providing  
20 tighter tolerances can be applied to manufacturing the  
blades).

Finally, the resultant of the unbalance caused by  
the set of blades (the full set) once mounted on the disk  
can be monitored by calculating a combined static  
25 residual moment relating to said blades (i.e. radial +  
tangential moment or radial + tangential + axial moment),  
and the selection criterion can usefully be extended to  
take this into account. This additional selection  
criterion corresponds to determining the unbalance of the  
30 residual radial and tangential static moments (or radial,  
tangential, and axial static moments depending on the  
intended embodiment) for all of the blades, which  
residual moment should not be greater than a fourth  
predetermined value, preferably equal to  $6 \times 10^{-4}$  m.kg (for  
35 radial + tangential moment) or to  $1 \times 10^{-4}$  m.kg (for radial  
+ tangential + axial moment) in order to ensure that the  
rotor as a whole is not rejected.

An example of implementing the method of the invention is shown in Figures 4A to 7B. This example relates to a fan rotor having a set of 24 blades (numbered 1 to 24), with the 3D static moments being measured in this example on 26 sets of 24 blades (i.e. 624 blades).

Figure 4A shows the values of the various radial static moments measured for each of the blades in these 26 sets. In the example shown, these moments vary in the range 201,000 cm.g to 215,000 cm.g. The distribution of these moments in terms of their values is plotted in Figure 4B. Similarly, Figure 5A gives the values of the various tangential static moments measured for each of the blades in the range 950 cm.g to 1850 cm.g. The distribution of these moments in terms of their values is plotted in Figure 5B. Figure 6A gives the values of the various axial static moments measured for each of the blades in the range 4150 cm.g to 5150 cm.g. The distribution of these moments in terms of their values is plotted in Figure 6B. It is then possible to classify these blades in pairs so that on each occasion the difference in static moment is less than the first predetermined value, i.e. 200 cm.g in this example, and the difference in tangential static moment is less than the second predetermined value, i.e. 300 cm.g in this example, with the difference in axial static moment being less than the third predetermined value, i.e. in this example likewise 300 cm.g. This leads to the following table:

Blade pair No.	Radial SM difference	Axial SM difference	Tangential SM difference
1 (blades 1 & 13)	20	100	70
2 (blades 2 & 14)	60	120	110
3 (blades 3 & 15)	100	270	280
4 (blades 4 & 16)	20	250	140
5 (blades 5 & 17)	30	170	220
6 (blades 6 & 18)	60	80	60
7 (blades 7 & 19)	30	0	140
8 (blades 8 & 20)	50	210	260
9 (blades 9 & 21)	80	100	30
10 (blades 10 & 22)	140	150	110
11 (blades 11 & 23)	60	170	40
12 (blades 12 & 24)	60	160	240

Preferably, it is then ensured that the radial (R) + tangential (T) + axial (A) resultant of the unbalance of the full set of blades (also referred to as the blading unbalance) is less than a fourth determined value which is equal to 100 cm.g in this 24-blade example. Figure 7A gives the values of the various combined static moments ( $R+T+A$ ) as measured for each of the 26 sets. These moments vary in the range 11 cm.g to 80 cm.g, so they are indeed less than 100 cm.g. The distribution of these residual moments in terms of their values is shown in Figure 7B. It should be observed that in the event of this blading unbalance departing from the authorized limit value, it is necessary to resort to permutations or changes of pairs in order to find a value that is more compatible with the required limit.

In the above example, the 26 sets of 24 blades were distributed on the basis of 3D static moments, however it is also possible under less favorable circumstances to proceed on the basis of the radial and tangential static moments only. Under such circumstances, the resultant

blading unbalance should be verified on the basis of the radial + tangential (R+T) resultant of the static moment alone.

The method of the invention as described for a set  
5 of 24 blades is naturally also applicable to an arbitrary number of blades forming a subset of the blades that are regularly distributed around the circumference of a turbomachine rotor.